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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff Rector, TU Ilmenau	Professor Christoph Ament Head of Organisation

Table of Contents

C O N T E N T S

Page

1 Systems Engineering and Intelligent Systems

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

52nd Internationales Wissenschaftliches Kolloquium
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T. Glotzbach / M. Marinov / P. Otto / M. Schneider

A Concept for Team-Orientated Mission Planning and Formal Language Verification for Heterogenous Unmanned Vehicles

ABSTRACT

This paper proposes a concept for the team-orientated mission planning (TOMP) and Formal Language Verification (FLV) of several unmanned vehicles with a focus on marine surface and underwater crafts. The use of several heterogeneous unmanned marine vehicles is a goal of the European Research project GREX[1] in which framework this work is done. It is important to use an approach that prevents the operator from the necessity to perform the planning for all participating vehicles. We will describe the process of upgrading an existing software tool for marine vehicle mission planning to the ability of performing Team-Orientated Mission Planning, translating team mission plans to single vehicle mission plans and executing a Formal Language Verification to guarantee the feasibility of the team- and the single vehicle mission plans.

INTRODUCTION

It is important for the success of the GREX-project that the users have the possibility to perform the mission planning on a simple way, without the necessity to know all the technical details. Therefore there is the need for a meta-language to formulate team mission plans in an understandable way and also for a software editor that allows a simple editing. The realisation of a manageable mission editor is a special challenge. The editor has to accept two main tasks: The mission planning is performed in an offline mode before the mission starts. The same interface shall be used to analyse the past mission summary of the data collected from the swarm members. If an intervention of a human operator ought to be allowed during the mission, it will also be performed with this user interface.

[1] The research project GREX, FP6-IST-2006-035223 is funded by the Sixth Framework Programme of the European Community

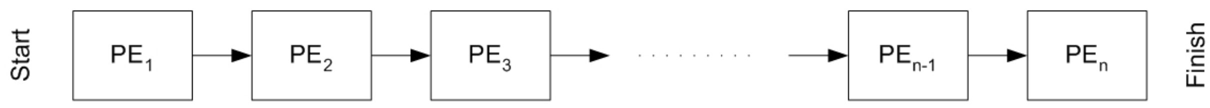

Figure 1: A sequential Mission Plan

According to the inputs of the operator, the editor software builds up a mission plan, which is composed of single plan elements. Every plan element describes a complex plot for the mobile systems. According to Figure 1, the mission plan can be stated as a linear sequence of plan elements (mission elements) that will further be referred as Vehicle Primitives. The advantage of sequential plans in opposite to parallel ones is that it is simpler for a human operator to create. For that reasons, many applications with autonomous systems (especially with Unmanned Air Vehicles, UAVs, and Autonomous Underwater Vehicles, AUVs) use sequential mission plans. [1] – [3]

The GUI for GREX Mission Planning will base on SeeByte's SEETRACK [4], the de facto standard common operator interface for mission planning, monitoring and post mission analysis with sensorised remote assets and their data products. SeeTrack has at this stage the ability to plan, execute and analyse the missions of single autonomous marine vehicles and will be empowered during the project for the planning, executing and analysing of team missions. The concept of the software for cooperation between the vehicles is described in [5] and [6]

TEAM-ORIENTATED MISSION PLANNING (TOMP)

The operator needs to be released from the task to create the mission plans for every single vehicle. Every vehicle that will be used in GREX has already autonomous abilities, like reaching of a given position or the following of a certain track. These simple manoeuvres are called 'Single Vehicle Primitives' (SVPs) and are the ingredients of the vehicle's mission plan. It is not planned to directly give commands to the autopilots of the involved vehicles from the Team Level. The SVPs shall be used as they are tested and work properly for each vehicle. Another advantage is that these SVPs – as they are used for Mission Planning – are usually available for all marine vehicles. So no further information about the vehicles and their technical realisations is needed. This eases the implementation of the vehicles into the team and may also ensure confidentiality about the functionality of the vehicles what may be important for vehicle providers.

This results in the needs of two Meta-languages for team mission planning. One is the team-orientated Meta-language for mission planning which contains all actions that can be performed by a vehicle team, like moving on parallel tracks or following a plume. The elements of the team mission plan are called 'Multi Vehicle Primitives' (MVPs). They contain all necessary information and abilities for the predefined scenarios in the GREX project.

The other essential meta-language is a GREX-standardised language on vehicle level. It contains a couple of unitary SVPs to realise the missions defined by the MVPs. After the operator has planned the team mission plan, it will be translated to many single mission plans, one for each vehicle. This plans will be translated into the corresponding vehicle language by the 'GREX Interface Module' that in general is responsible for all interfaces between the existing hard- and software of the vehicles and the GREX-dedicated new ones. Figure 5 gives an overview on the described construction with the three language levels.

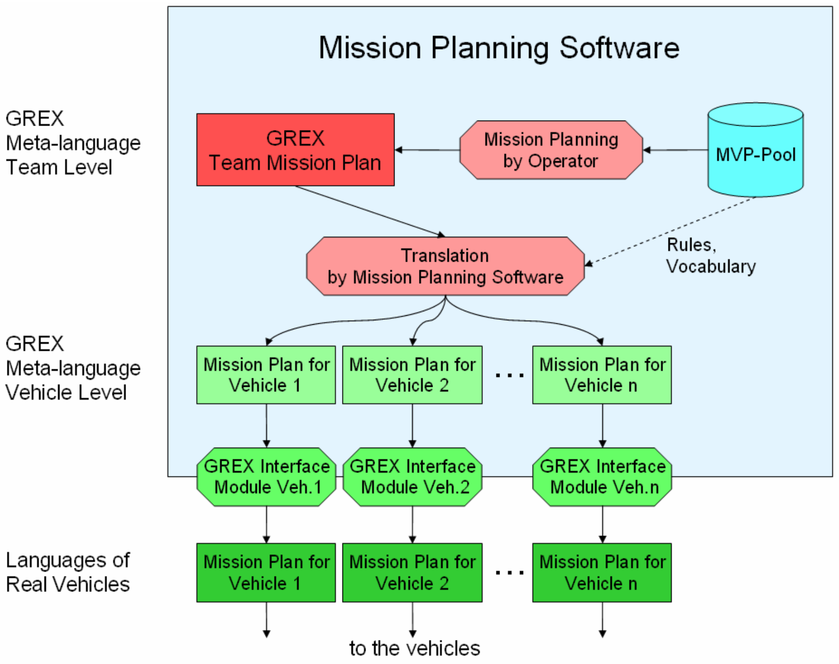

Figure 2: Concept of Team-Orientated Mission Planning

The proposed concept ensures the possibility to expand the mission- and vehicle-pool beyond the GREX-project. Every new mission simply needs to be described with MVPs. Possibly new MVPs need to be defined and translated into the meta-language on vehicle level. New vehicles can be introduced by developing an appropriate GREX Interface Module which in general is necessary not only for mission planning, but also for other tasks like navigation, communication, use of payload etc.

FORMAL LANGUAGE VERIFICATION (FLV)

The different mission plans must be subject to verification for syntax, semantic and logical execution of the mission. The goal of designing Formal Language Verification (FLV) is to present security layer in the GREX mission planning that can detect problems in execution of the mission plan and make the process of creating mission plan and its execution very reliable. To achieve this goal the Formal Language Verification must be accessible after the team mission plan is created of the MVPs, after the team mission plan is translated to the single vehicle mission plans, after the mission plan is uploaded on a specific vehicle and during execution of the mission plan on the vehicle. In every situation the FLV must be proceeded like shown on the Figure 3.

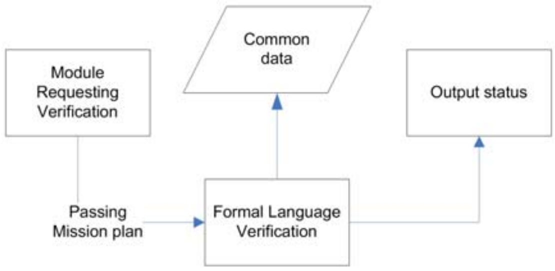

Figure 3: Formal Language Verification usage

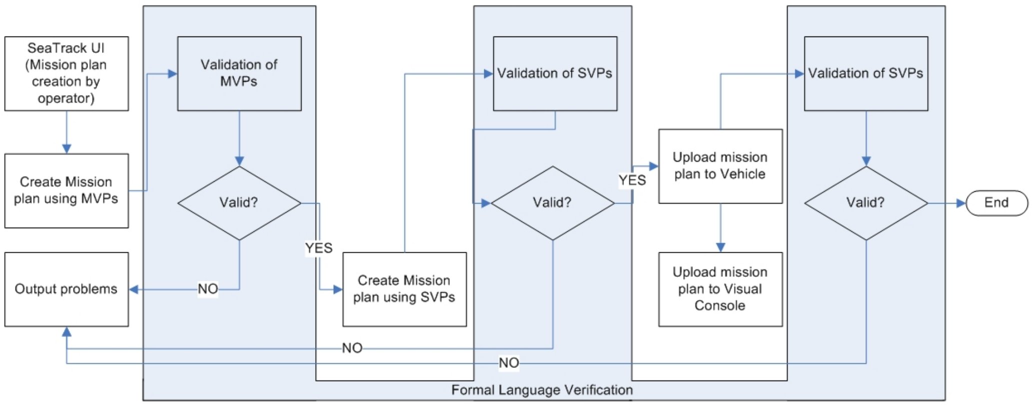

Figure 4: Mission plan creation and verification steps

The already defined steps for verification are integrated in the process of creating a working and verified mission plan that is ready for execution by a team of vehicles. Each mission plan must pass 3 levels of verification. During all of these three steps formal verification on the entire mission plan must be executed. As it can be seen from Figure 4 the first verification is made on MVPs but the other two steps on SVPs.

FLV is a process that must handle different verification aspects. Each of these aspects must be accessible as stand alone verification or as a sub step of another aspect of verification. The different types of verification can be described like this:

- Syntax and semantic verification – This type of verification has the goal to verify the correctness of the language that defines the current mission plan.
- Vehicle/Payload/Communication constraints verification – The objective of the verification is to prove that all parameters included in the mission plan are correct in relation to the constraints defined for each vehicle. In the meaning of team-oriented mission planning this verification is not mandatory but it is a must for single vehicle-oriented mission planning. However, this step can be performed to the team-oriented mission plan to guarantee that the parameters are not out of range for all vehicles. This kind of verification on the team-oriented mission plan will prevent the translation from MVPs in SVPs if the values are not correct.
- Logical verification – the last and most important kind of verification must define if the mission plan as it is designed can be executed by the selected vehicles. This verification requires all other verifications to be completed with success because only logical algorithms are applied to the mission plan to prove that it is executable.

This kind of verification has the following major objectives:

o Dependency verification.

One of the rules that must be valid so the mission plan can be executable is to have strong dependencies between every step. This requires that the execution of a specific step from the mission plan must result with parameters that are the same as the initial parameters for the next step.

o Behaviour verification.

During mission execution it is common for every vehicle to have some predefined behaviours that can be executed but not actually to be described in detail as a part of the mission plan. The objective of such verifications is to minimize the amount of work and the risk when validation of the mission plan is performed.

o Calculation verification.

The validity of the Mission plan is connected to calculations on every single step defined in the mission plan. The calculations are related with constraints defined by the vehicle, mission, communication, etc.

o Path validation.

Using the objectives above the FLV must be able also to verify the paths that are defined in the mission plan. One of the major issues in this validation is to simulate the paths of the vehicles and to verify that no collision or path intercept will occur during execution of the mission plan. If there are any interceptions of the vehicle’s path then the role of this verification is to calculate the approximate time that every vehicle will pass the point of interception and to report the result to the operator.

CONCLUSION

The design of a Team-Orientated Mission Planning for unmanned vehicles has to deal with a lot of facts. We presented a concept with three different levels of planning languages that allow a modular and generic mission planning. The process can easily be expanded for new missions or new vehicles. A Formal Language Verification was presented that executes different verifications and allows the online changing of plan parameters.

ACKNOWLEDGEMENTS

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